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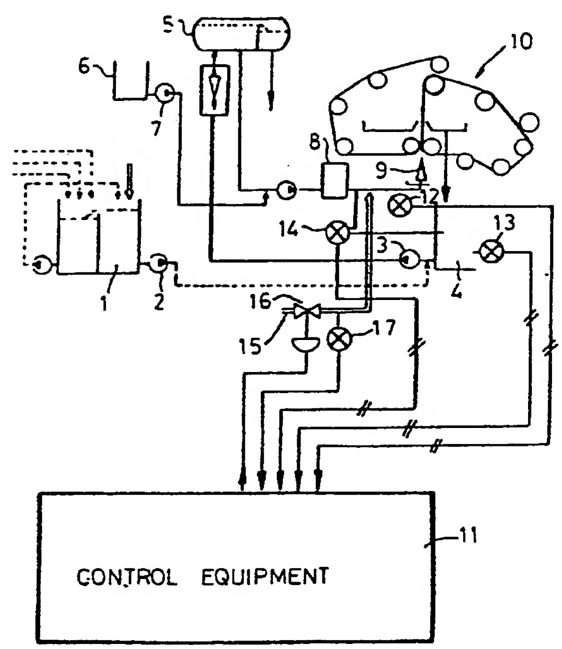
(54) Title: METHOD FOR MEASURING THE FIBRE AND FILLER CONCENTRATION IN THE WET END OF A PAPER MACHINE AND A CONTROL SYSTEM USING THE METHOD

(57) Abstract

A method for measuring the fibre/solid matter and filler concentration in the wet end of a paper machine utilises two optical transducers, one of which operates on infrared light and has a reference channel for temperature compensation, and the other operates on polarised light. The mutually different and nonlinear transducer output signal characteristics are determined experimentally prior to measurement for the fibre/solid matter and filler at issue. The output signals then obtained from the transducers for each measurement are combined on the basis of the transducer output signal characteristics experimentally determined prior to measurement, in order to provide a separate value of the fibre/solid matter concentration and a separate value of the filler concentration. A control system using this method comprises a control equipment (11) and at least two optical transducers (12, 13, 14). The control equipment is adapted to combine the transducer output signals from each measurement on the basis of the transducer output signal characteristics determined experimentally prior to measurement, in such a manner that a separate value of the fibre concentration/solid matter concentration and a separate value of the filler concentration are obtained. The addition of retention agent to the head box (9) of the paper machine is controlled by the control equipment in dependence on the calculated retention values.



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METHOD FOR MEASURING THE FIBRE AND FILLER CONCENTRATION IN THE WET END OF A PAPER MACHINE AND A CONTROL SYSTEM USING THE METHOD

The present invention relates to a method for measuring the fibre/solid matter and filler concentration in the wet end of a paper machine and a control system using the method.

In the manufacture of paper in a paper machine, the composition and thus the properties of the finished paper depend on, inter alia, the composition of the stock, i.e. the concentration of fibre and filler in the wet end of the machine, and on the retention of the said stock components in the paper web discharged from the wet end of the paper machine.

Normally, the composition of the stock is controlled by dosing, on a volume basis, the various stock components at predetermined constant concentrations. Also batched to the stock are a number of additives and the like including, inter alia, retention agents, starch, hydrophobing agents and wet strength agents.

The composition has previously been checked by measurements effected on the finished paper, or by taking stock samples which are then measured. Depending upon the result of these measurements, the dosing of the stock components and the additives was adjusted.

Up to the present time, this control technique has been sufficiently accurate because the paper properties have been comparatively insensitive to minor variations of the additives.

Nevertheless, it has been tried to carry out continuous measurements of fibre/solid matter and filler concentrations in the wet end of the paper machine. One example of prior art technique for carrying out selective measurements of fibre/solid matter and filler concentrations in the wet end of a paper

machine is a recommendation (SE-A-8400784-8) which involves using a densimeter for measuring the density of the suspension, i.e. the density of the liquid and the substances suspended therein, a particle concentration meter for measuring the relationship between the volume of the suspended substances and the volume of the liquid, and a calculating unit for determining the concentration of two suspended substances by linearly combining the values measured with the densimeter and the concentration meter. This technique is inadequate, on the one hand because the concentration meter depends on a certain minimum particle size and, on the other hand, because the value measured with the densimeter depends both upon temperature and upon the presence of air in the liquid. The temperature dependence may be compensated for, but the air dependence can be but partly compensated for, and this is done by increasing the pressure on the liquid in the densimeter.

Methods alternative to density measurement and useful for indirectly measuring the concentration of various stock components may be based on, for example, the viscosity, the absorption of radioactive radiation, the damping of supersonic sound, or the damping or scattering of light. However, none of these methods is in itself sufficiently selective to be able to provide directly the desired information about the fibre/solid matter and filler concentrations in the wet end of a paper machine, and furthermore, they cannot be simply combined linearly according to prior art technique.

The development of various additives has made it possible to improve the properties of the finished paper in several respects and to adapt the paper to the contemplated use. At the same time, however, the sensitivity to variations in the concentrations of the various components in the wet end has become higher. Furthermore, a dynamic dependence has arisen, such

that the best concentration of one component will also depend on the preceding concentration of this and other components.

The development described above has greatly increased the need for a continuous and accurate technique for measuring the concentrations of the various stock components, especially the fibre and filler concentrations in the wet end of the paper machine.

One object of the present invention is to satisfy this need, and this object is achieved in that the method is given the characteristic features stated in the appended independent method claims.

A further object of the present invention is to provide a control system which makes it possible to achieve, by utilising the above-mentioned method, optimal control of the added amount of chemicals primarily affecting the retention.

This further object is achieved in that the control system is given the characteristic features stated in the appended independent system claims.

It has thus been established that the desired exact concentration values are obtainable by means of two optical concentration meters which are based on different physical principles and the output signals of which have discrete correlations to the concentration of fibre/solid matter and to the concentration of a filler. According to the invention, use is made in this context of an experimental advance determination of the nonlinear dependence of the output signal of the respective concentration meter on the concentration of fibre/solid matter, and its nonlinear divergent dependence on the concentration of a filler.

More particularly, one of the optical concentration meters is of the type utilising infrared light which is transmitted from a source of infrared light through a volume through which the sample liquid passes continuously, to a detector of infrared light. This meter

measures the extinction of the infrared light from the source by the sample liquid, i.e. the reflection of the suspended particles and the absorption of the light. Theoretically, the extinction is logarithmically dependent on the concentration, but the dependence is not univocal when fibre/solid matter and filler are present simultaneously. In addition, the dependence is sensitive to the temperature of the sample liquid. This concentration meter therefore usually has a built-in reference channel for temperature compensation, and compensation is accomplished in that infrared light is also transmitted through a reference volume of a liquid of known extinction and having essentially the same temperature as the sample liquid.

The other optical concentration meter utilises polarised light which also is transmitted through a volume through which the sample liquid passes continuously. The depolarising effect of the sample liquid on the light is determined by means of two detectors, the first of which is sensitive to light having an unvaried plane of polarisation, while the second detector is sensitive to light having a plane of polarisation rotated through 90°. Here, the output signal of the first detector, related to the output signal of the second detector, is concentration dependent, but not temperature dependent. The measured value supplied by this second concentration meter thus is concentration dependent but, as is the case with the first concentration meter, the dependence is not univocal if fibre/solid matter and a filler are simultaneously present.

Both of the optical concentration meters described have a nonlinear dependence upon the concentrations of both fibre/solid matter and filler. The output signals of the meters furthermore have different correlations both to the concentration of fibre/solid matter and to the concentration of a filler, which

is a prior condition for the proper functioning of the invention. By experimentally establishing in advance the output signal of each meter within the concentration range at issue separately for fibre/solid matter and filler, regard can be paid to nonlinearities, also different nonlinearities, in each individual case.

The invention will be described in more detail below, reference being had to the accompanying drawings. Fig. 1 illustrates an embodiment of the wet end of a paper machine with the control system according to the invention. Fig. 2 is a diagram showing the change of a paper grade parameter in dependence on two additives. Fig. 3 is a diagram generally showing the output signal from an example of an available concentration detector. Figs. 4A-C show examples of output signals from a first optical concentration meter that may be used in accordance with the present invention, at different concentrations of fibre and filler. Figs. 5A-C show examples of output signals from a second optical concentration meter that may be used in accordance with the present invention, at different concentrations of fibre and filler. Fig. 6 is a diagram showing an example of how changes in the flow of a retention agent affect the retention of a stock component.

The paper machine part illustrated in Fig. 1 comprises a mixing tank 1 in which the fibre and filler components of the stock are mixed and from which the stock is supplied, by means of a pump 2, to the inlet side of a white water pump 3 pumping white water from a wire pit 4 to a level control tank 5 from which the stock, after admixture of additives from an additive supply 6, is conveyed by means of a pump 7 to a machine tank 8 from which the stock with the additives supplied thereto reaches the machine head box 9 which distributes the stock on the wire part 10. The white

water drained from the wire part 10 is supplied to the wire pit 4.

The control system according to the invention comprises a control equipment 11 having inputs from a separate transducer 12 in the head box 9, a separate transducer 13 in the wire pit 4, and a transducer 14 which is alternately connectible to the wire pit 4 and the head box 9. The transducers 12, 13 and 14 are utilised together in the manner described below for determining the filler concentration and the fibre/solid matter concentration in the head box 9 and the wire pit 4.

Fig. 1 also shows a separate conduit 15 for adding the retention agent, said conduit being connected to the inlet side of the head box 9. To control the supplied flow of retention agent, a control valve 16 is provided which is controlled from the control equipment 11. Furthermore, there is a flow sensor 17 which also is connected to the control equipment 11.

Fig. 2 illustrates the difference between the effect of older additives and more modern additives upon a property of the paper made. In the left-hand part of the diagram, the level of a curve indicates the quality of the property in question, and it will be seen that the property is relatively invariable with the time. The right-hand part of the diagram shows how a quality increase can be obtained with a more modern additive, but at the same time the variations in the quality of the property are increased. Consequently, it would be desirable that one can carefully control the addition of the additive continuously and on the basis of the quality changes obtained. In order to realise a working control system for optimising desirable properties of the paper made, the present invention has devised a method for measuring the fibre/solid matter and filler concentrations in the wet

end of a paper machine. More particularly, this method makes use of two optical meters or transducers which are based on two different physical principles, for example, the transducers 13 and 14 which are described in more detail below and whose output signals have separate correlations, experimentally determined in advance, to the fibre/solid matter and filler concentrations, respectively. The output signals from these optical transducers 13 and 14 are combined in the control equipment 11 in a manner such that a separate value of the fibre concentration/solid matter concentration and a separate value of the filler concentration in the wire pit 4 is obtained. The output signals from the optical transducers 12 and 14 are combined in the same manner in order to obtain a separate value of the fibre concentration/solid matter concentration and a separate value of the filler concentration in the head box 9.

In accordance with the invention, and as will appear from the embodiment illustrated in Fig. 1, the fibre/solid matter concentration and the filler concentration are determined both in the head box 9 and in the wire pit 4, whereby a value of the retention can be compiled from these concentrations. According to the invention, the addition of a retention agent to the head box 9 can preferably be controlled by the control equipment 11 in dependence on the compiled retention values, and be controlled by means of the flow control valve 16.

According to the invention, considerable cost savings are obtained in that the optical transducer 14 is utilised alternately as a transducer in the head box 9 and as a transducer in the wire pit 4. However, the transducer 14 may of course be doubled.

The fact that transducers which are directly and selectively sensitive to merely the concentration of a specific stock component, are unobtainable on

the market, is of little consequence to the present invention which utilises two optical transducers based upon different physical principles. In this manner, it is possible to utilise optical transducers whose output signal certainly is correlated to the concentration of one stock component, but also is dependent upon the concentration of another stock component. The characteristic of such a nonselective detector is generally shown by the diagram in Fig. 3 from which it appears that the output signal of the detector is directly related to the fibre concentration in the stock, but also is dependent upon the filler concentration therein.

According to the invention, the optical transducer, for example the transducer 12 or 13, is a transducer operating on infrared light. More particularly, it comprises a light-emitting diode as a source of infrared light, and a photodiode as a detector of this light which is transmitted by the light-emitting diode against the photodiode transversely through a pipe conduit which constitutes a sample volume and through which a part of the stock of the head box 9 and a part of the liquid of the wire pit 4 flow continuously. The transducer contains a further light-emitting diode for infrared light which, via a reference volume of a liquid of known extinction, is directed against a further photodiode. The output signal from said further photodiode is utilised in the transducer in order to compensate for any changes in the output signal of the first-mentioned photodiode due to temperature variations. A transducer of the type here described may be, for example, the concentration meter "ACM" from Cerlic Controls AB. The output signal characteristics of this meter for chemical pulp fibres, chalk and clay are shown in percent in Figs. 4A, B and C, respectively, from which it appears that the characteristics are nonlinear and different for fibre

and each of the fillers. Fig. 4A relates to bleached chemical pulp, but the tranducer will be useful also for woodpulp and unbleached chemical pulp. It can be used also for, for example, titanium dioxide. The same applies to the optical transducer described below.

According to the invention, the other optical transducer, for example the transducer 14, is a transducer operating on polarised light. In this case, the light suitably lies within the visible region. Also in this transducer, the light is transmitted transversely through a pipe conduit which constitutes a sample volume and through which part of the stock of the head box 9 flows alternately with a part of the liquid of the wire pit 4.

During the alternation between stock and liquid, the pipe conduit is flushed with water. In addition to the financial gain made possible by the common transducer 14, the alternation between stock and white water has proved to be advantageous in that it prevents the accumulation of fibre/solid matter and filler on the walls of the sample volume.

The other optical transducer has two detectors, of which the first is sensitive to light having the same plane of polarisation as the light transmitted into the sample volume, while the other detector is sensitive to light having a plane of polarisation rotated through 90° relative to said first-mentioned plane of polarisation. The output signal from the other transducer is a combination of the output signal of the first detector and the output signal of the second detector. A transducer of the type here described may be, for example, the concentration meter "LC-100" from Kajaani Electronics Ltd. The output signal characteristics of this meter for chemical pulp fibre, chalk and clay are shown in Figs. 5A, B and C, respectively, as voltage values. As will appear from these Figures, also these characteristics are nonlinear

and mutually different. They are also different from the characteristics according to Figs. 4A-C for the first transducer.

As will appear from the above, the present invention may be used for determining the concentration of a filler, but also the concentration of several fillers if the relationship therebetween is known.

By utilising, in accordance with the present invention, two optical transducers which are based upon different physical principles and thus respond differently to, for example, fibre concentration and filler concentration, the control equipment 11 can compile a separate value of the fibre concentration/solid matter concentration and a separate value of the filler concentration. For practical purposes, this can be done in different ways. Thus, theoretically devised characteristics of fibre/solid matter and filler may be corrected on the basis of the results obtained by the experimental advance determinations. Alternatively, the experimentally devised characteristics may be stored in table form and utilised more directly. Generally, the transducer output signals from each measurement are combined on the basis of the transducer output signal characteristics determined experimentally prior to measurement, in order to provide a separate value of the fibre/solid matter concentration and a separate value of the filler concentration.

More particularly, the method according to the invention utilises the fact that the concentration C of a substance in the stock or the white water can be expressed, with the transducers employed, as

$$C = S_C/k$$

wherein k is a coefficient which is specific to each substance and which is determined experimentally, and S_C is a nonlinear theoretically determinable function

of the direct output signal of the transducers, the raw signal. S_c is here referred to as the corrected signal. The nonlinear function must be different for the two transducers. In this manner, it is possible to determine the concentrations of two substances in, for example, the stock by means of a linear equation system of the type

$$S_{c1} = k_{11} \cdot C_1 + k_{12} \cdot C_2$$
$$S_{c2} = k_{21} \cdot C_1 + k_{22} \cdot C_2$$

wherein S_{c1} and S_{c2} are the corrected signals of the two transducers, k_{11} and k_{12} are the coefficients, specific to the two substances, of one transducer, k_{21} and k_{22} are the coefficients, specific to the two substances, of the other transducer, and C_1 and C_2 are the concentrations of the two substances.

As a consequence of different types of interaction between the two substances, if present at the same time, the values of the concentrations C_1 and C_2 obtained with the above equation system are not entirely correct. In accordance with the invention, coefficients k_{11}, k_{12}, k_{21} and k_{22} therefore are corrected experimentally on the basis of values of the concentrations C_1 and C_2 determined by sampling with other means. In the following, the corrected signals obtained by means of the respective nonlinear function from the two transducers and the experimentally corrected coefficients k_{11},k_{12}, k_{21} and k_{22} are utilised to determine the concentrations C_1 and C_2. In this manner, the invention guarantees highly exact concentration values.

By comparing the obtained values with reference values or previously obtained values, a decision can be taken as to whether the supplied amount of retention agent must be changed or not. The control equipment 11 then controls the setting of the flow control valve 16, whereupon the measurement is repeated and the

addition of the retention agent can be relatively quickly optimised.

Curve A in the diagram according to Fig. 6 illustrates the varying quantity of a stock component in the head box of the paper machine, while curve B illustrates the component quantity carried along with the white water for the same component. Curve C illustrates variations in the flow of the supplied retention agent, and curve D illustrates the resulting retention. As will appear from Fig. 6, positive retention variations are obtainable either by reducing the amount of the supplied retention agent or by increasing the supply thereof.

Preferably, the control equipment 11 is adapted to store concentration values - referable to different times - of different stock components so that dynamically varying amounts of the stock components can be calculated. In this instance, the control equipment 11 makes an adaptive control which at all times endeavours to maximise the retention while utilising a minimum amount of retention agent.

Finally, it should be emphasised that the method and the system according to the present invention are not restricted to the wire type illustrated in the embodiment according to Fig. 1, but are applicable independently of the wire type. The invention may also be used for controlling the addition of several retention agents.

CLAIMS

1. A method for measuring the fibre/solid matter and filler concentration in the wet end of a paper machine, c h a r a c t e r i s e d in that use is made of two optical transducers, one of which operates on infrared light and has a reference channel for temperature compensation, and the other operates on polarised light; that the mutually different and non-linear output signal characteristics of the transducers are determined experimentally before the measurement for the fibre/solid matter and filler at issue; that the output signals then obtained from the transducers for each measurement are combined on the basis of the output signal characteristics of the transducers experimentally determined prior to measurement, in order to provide a separate value of the fibre/solid matter concentration and a separate value of the filler concentration.

2. A method as claimed in claim 1, c h a r a c t e r i s e d in that the fibre/solid matter concentration and the filler concentration are determined both in the head box and in the white water, and that a value of the retention is compiled from these concentrations.

3. A method as claimed in claim 2, c h a r a c t e r i s e d in that the addition of a retention agent to the head box is controlled in dependence on the retention values compiled.

4. A method as claimed in claim 2 or 3, c h a r a c t e r i s e d in that at least one of the transducer is utilised alternately as a transducer in the head box and as a transducer in the white water.

5. Control system using the method as claimed in any one of claims 1-4, c h a r a c t e r i s e d by a control equipment (11) and at least two optical

transducers (12, 13, 14), one of which operates on infrared light and has a reference channel for temperature compensation, and the other operates on polarised light, the mutually different and nonlinear output signal characteristics of the transducers having been determined experimentally prior to measurement for the fibre/solid matter and filler at issue, and said control equipment being adapted to combine the output signals from the transducers at each measurement on the basis of the transducer output signal characteristics determined prior to measurement, such that a separate value of the fibre concentration/solid matter concentration and a separate value of the filler concentration are obtained, the addition of retention agent to the head box (9) of the paper machine being controlled by the control equipment in dependence on the retention values calculated.

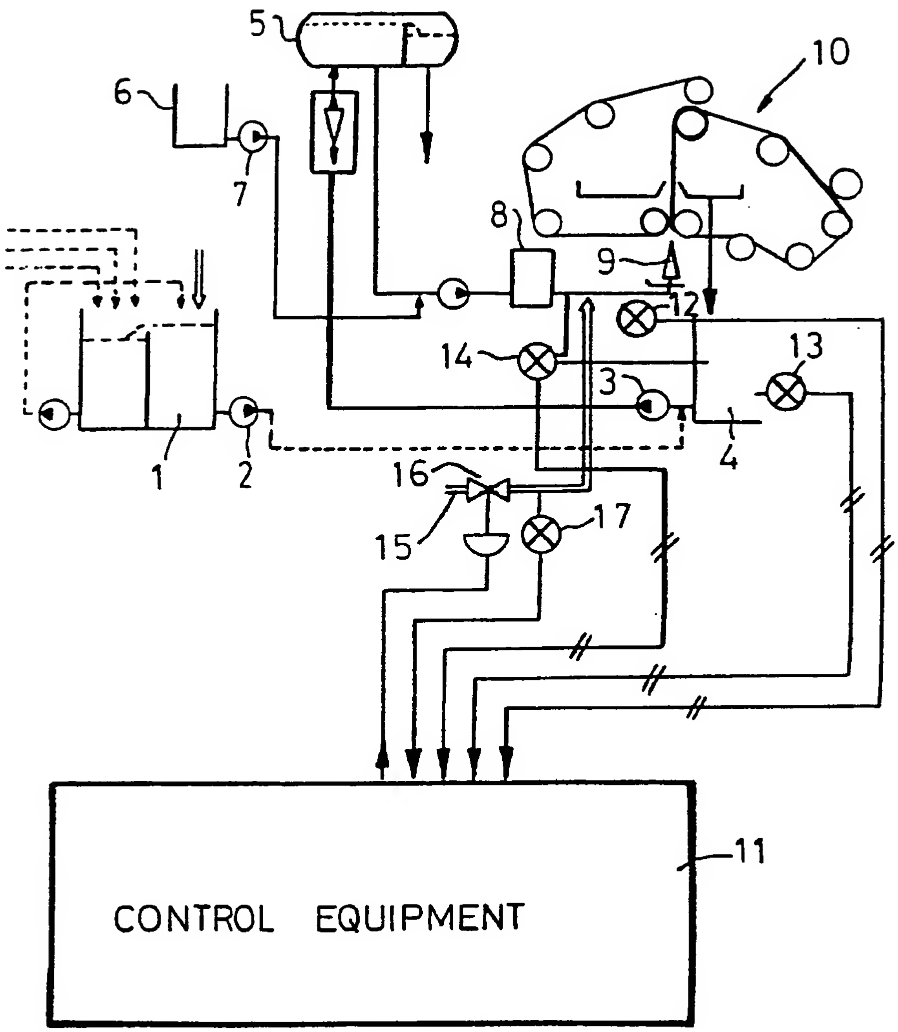


FIG. 1

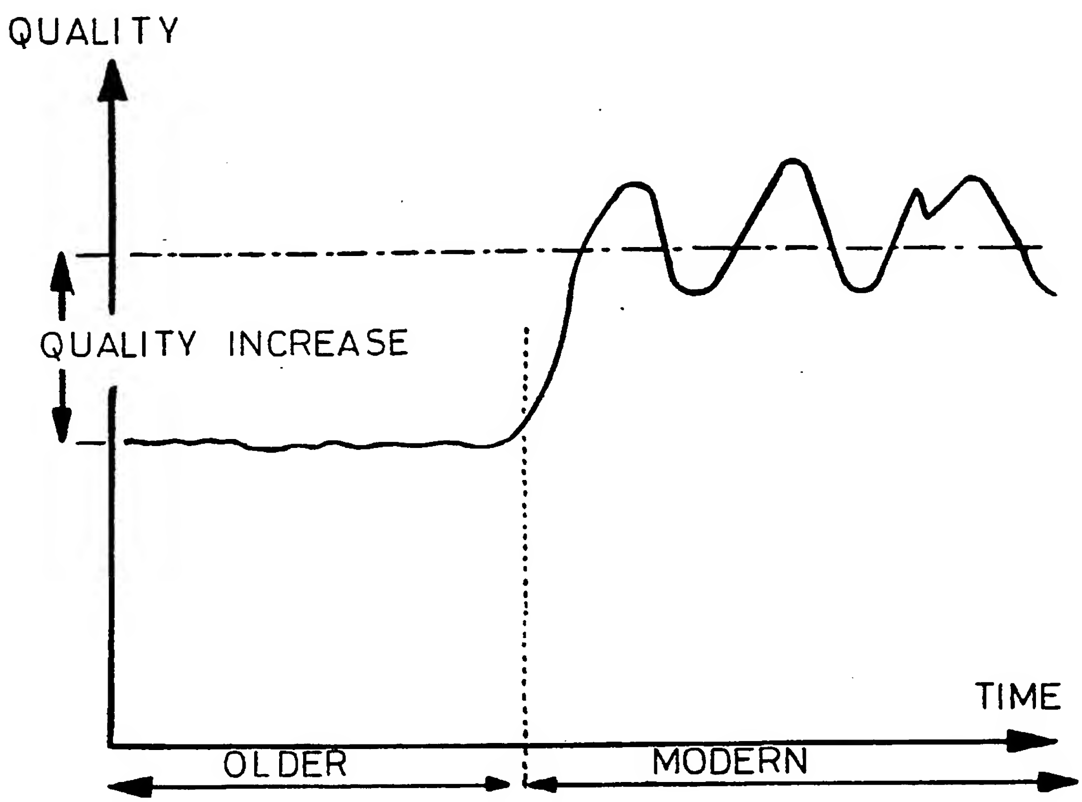
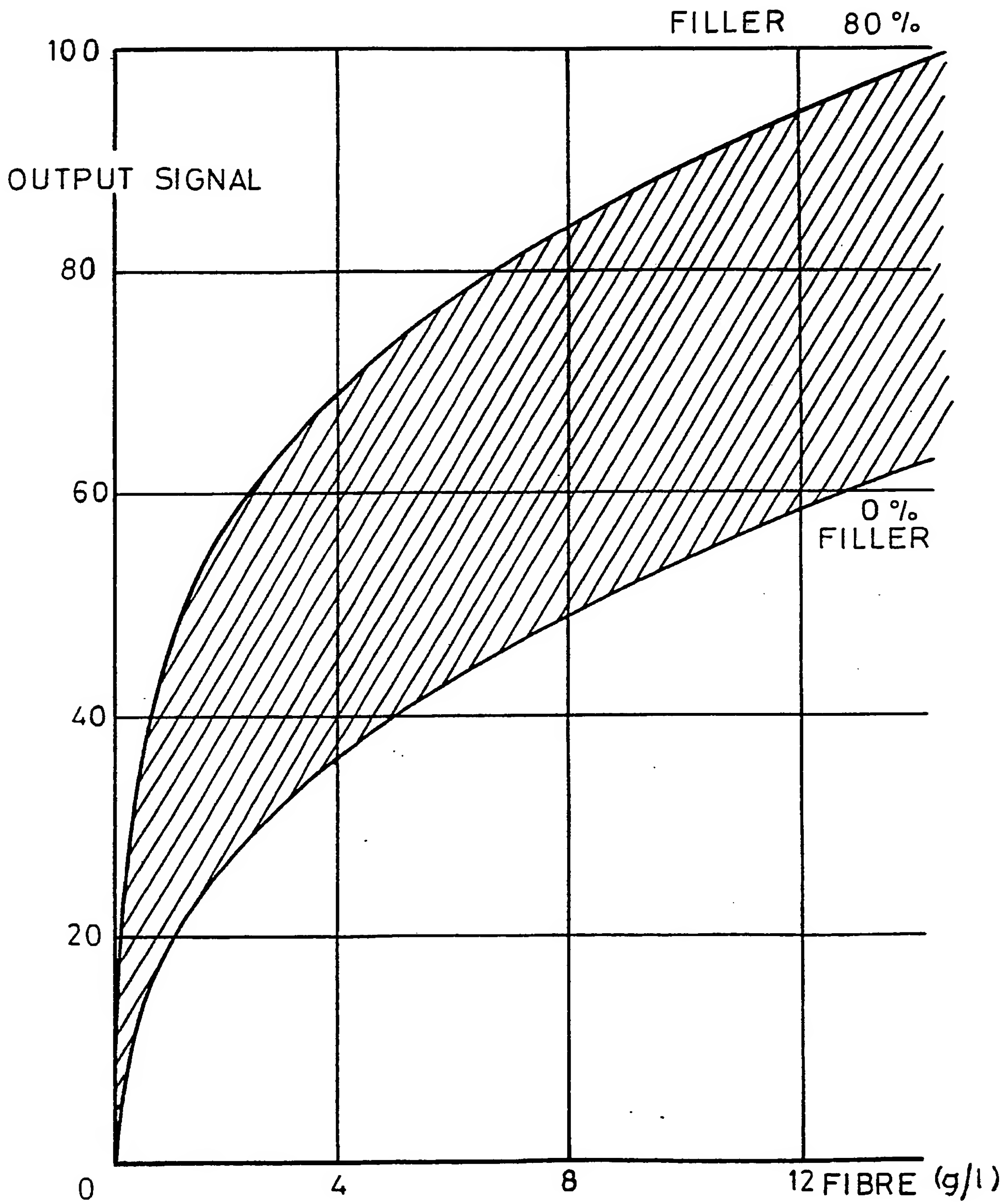


FIG. 2

FIG. 3


FILLER 80 %
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OUTPUT SIGNAL
80
60
0 %
FILLER
40
20
0
4
8
12 FIBRE (g/l)

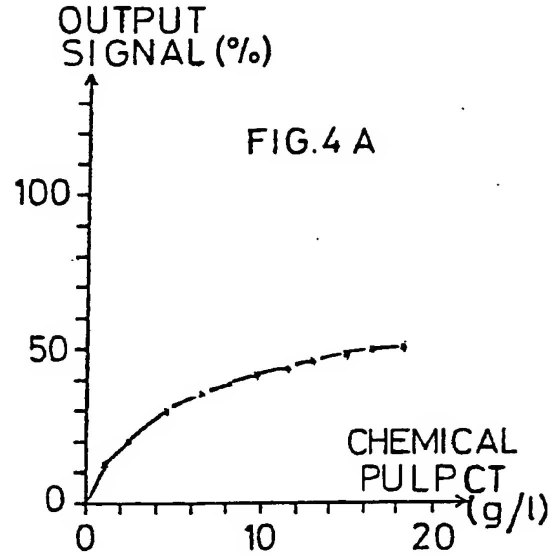

FIG.4 A

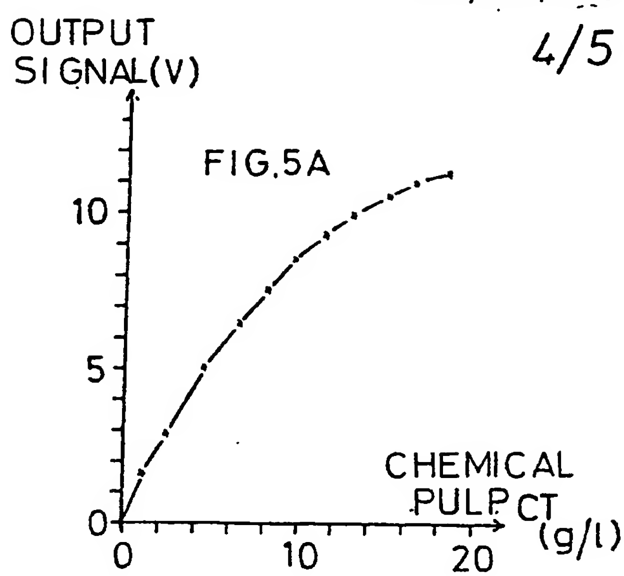

FIG.5A

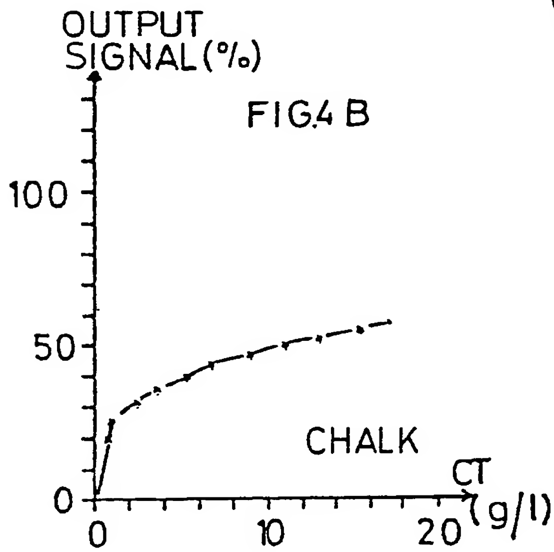

FIG.4 B

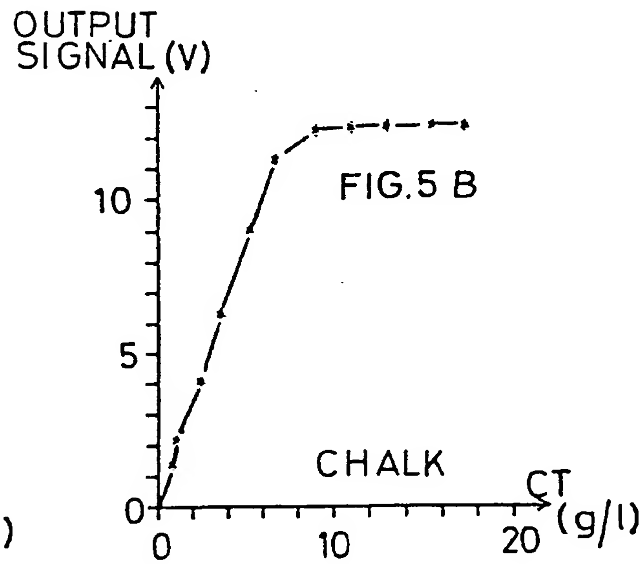

FIG.5 B

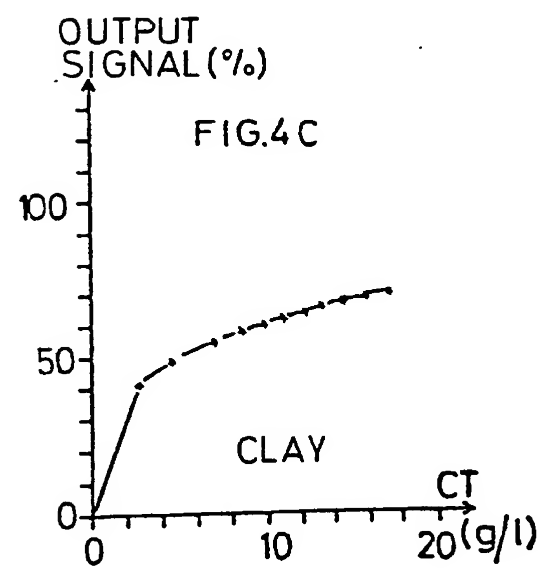

FIG.4 C

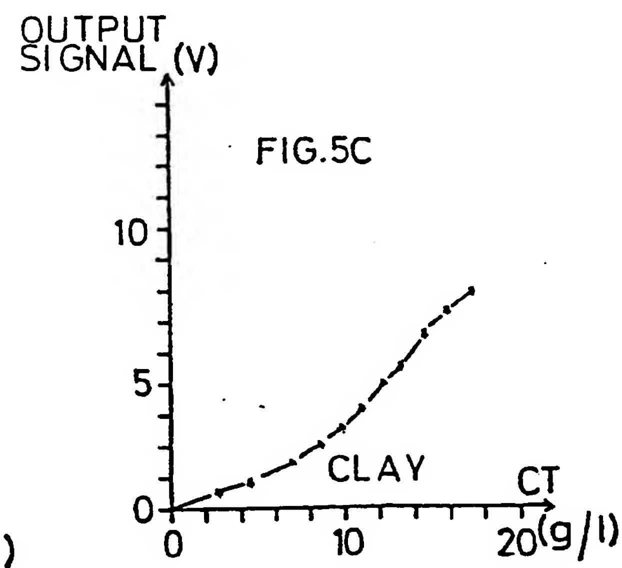

FIG.5C

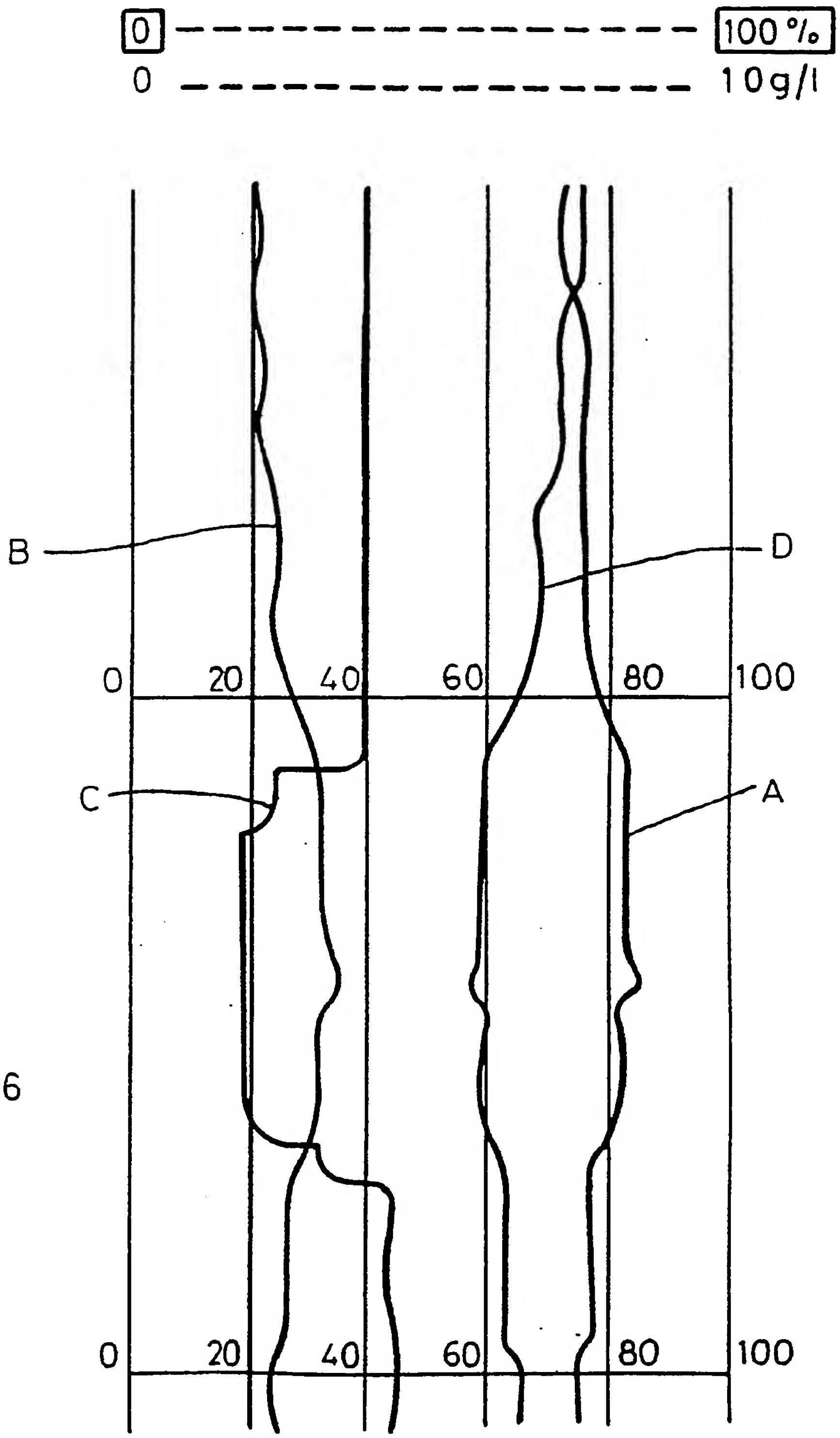

FIG. 6

CORRECTED

INTERNATIONAL SEARCH REPORT

International Application No PCT/SE86/00270

I. CLASSIFICATION OF SUBJECT MATTER (if several classification symbols apply, indicate all) [6]

According to International Patent Classification (IPC) or to both National Classification and IPC 4

G 01 N 21/85, 21/17, 15/06

II. FIELDS SEARCHED

Minimum Documentation Searched [7]

Classification System	Classification Symbols
IPC 2	G 01 N 21/26, /28, /34, /40
IPC 4	G 01 N 21/17, /21, /35/, /85, /89, 15/06
US Cl	356: 104, 116, 206, 208, 212, 435, 436, 441

Documentation Searched other than Minimum Documentation to the Extent that such Documents are Included in the Fields Searched [8]

SE, NO, DK, FI classes as above

III. DOCUMENTS CONSIDERED TO BE RELEVANT [9]

Category *	Citation of Document, [11] with indication, where appropriate, of the relevant passages [12]	Relevant to Claim No. [13]
Y	US, A, 3 724 957 (TAMATE ET AL) 3 April 1973 see fig 9-11	1-5
Y,P	SE, B, 442 247 (SVENSKA TRÄFORSKNINGSINSTITUTET) 9 December 1985 & WO, 85/03774 EP, 0174946	1-5
Y	WO, A1, 81/01467 (SVENSKA TRÄFORSKNINGSINST.) 28 May 1981 & EP, 0039718 SE, 8008145 CA, 1162074	1-5
Y	US, A, 3 468 607 (G E SLOANE ET AL) 23 September 1969 & GB, 1157718 DE, 1648932	1-5
Y,P	WO, A1, 86/02162 (APM LIMITED) 10 April 1986 & AU, 49565/85	1-5

.../...

* Special categories of cited documents: [10]

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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step

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IV. CERTIFICATION

Date of the Actual Completion of the International Search	Date of Mailing of this International Search Report
1986-08-27	1986 -08- 28
International Searching Authority	**Signature of Authorized Officer**
Swedish Patent Office	Kristina Bilton

IH

Form PCT/ISA/210 (second sheet) (January 1985)

BAD ORIGINAL

International Application No. PCT/SE86/00270

III. DOCUMENTS CONSIDERED TO BE RELEVANT (CONTINUED FROM THE SECOND SHEET)		
Category *	Citation of Document, with indication, where appropriate, of the relevant passages	Relevant to Claim No
A	US, A, 3 518 003 (F W MEYN) 30 June 1970	
A	WO, A1, 84/04594 (THE BROKEN HILL PROPRIETARY COMPANY LIMITED) 22 November 1984	
A	JP, Patent abstract of Japan, 56-142458, SANYO KOKUSAKU PULP K K, 6 November 1981, Vol 6	
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